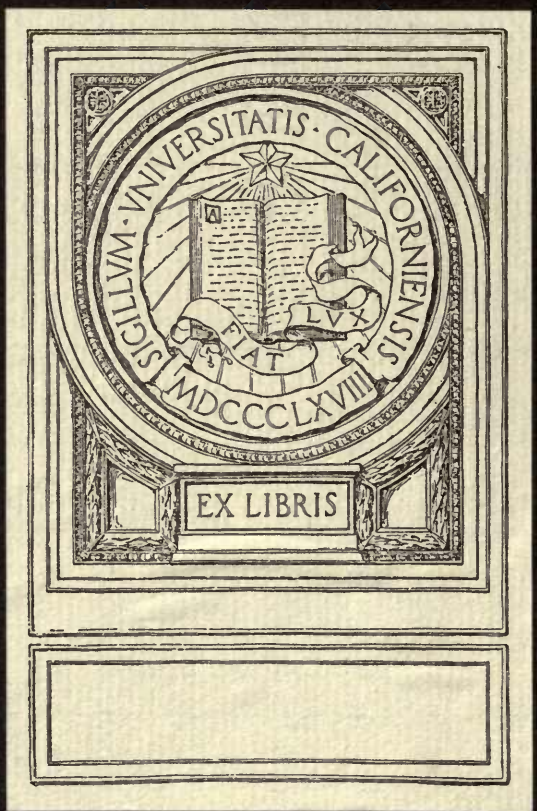
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NOTE

ON

WATER REQUIRED AND AVAILABLE

FOR THE

SUDAN GEZIRA SCHEME.

MAY 1918.

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CONTENTS.

NOTE

ON WATER REQUIRED AND AVAILABLE FOR THE SUDAN GEZIRA SCHEME.

In considering the Irrigation of the Sudan Gezîra,* its geographical situation must be kept in mind. It is a triangular tract, bounded on the east by the Blue Nile and on the west by the White Nile, which join at its apex to form the Nile. The joint supply of these rivers passing thence to Egypt is not equal in kind or quantity throughout the year. During the first half of the year the bulk of the supply to the Main River comes from the White Nile: during the second half of the calendar conditions are reversed and the immense volume of the Nile Flood comes from the Blue Nile. The Gezîra plain has a north-westerly fall and can only be irrigated from the Blue Nile.

It requires to be proved for what area the Blue Nile can provide, or be made to provide, sufficient water at the time of year when the Gezîra is to be cultivated. It also requires to be shown that the use of water for the Sudan need not diminish Egypt's supply. These proofs are required principally and in the first instance in regard to the irrigation of a small part of the Gezîra, not exceeding 300,000 feddâns.† Proof is easy and shows great margins of safety. The Blue Nile can be shown to be very much more than sufficient for the area proposed. The 300,000 feddâns can be shown to be capable of irrigation from the Blue Nile without any diminution at all of Egypt's supply, and when the Blue Nile is further devoted to the Sudan, Egypt has, in the White Nile, enormous resources in reserve.

Some years ago, when the proposal to irrigate a portion of the Gezîra first came up, it was anticipated that the Blue Nile flow would warrant the cultivation of at least 750,000 feddâns.† Subsequently to this the phenomenally low flood of 1913 occurred, entailing the low winter and spring levels of 1914. In 1916–1917, a further preliminary estimate was got out in the light of newer knowledge. The supply consequent on the nature of the works proposed was then estimated to be capable of irrigating 510,000 feddâns in the worst known year and 900,000 feddâns in the next lowest year, with a relatively small reservoir capacity at the proposed Sennâr Dam. It was

* The Northern Gezîra plain, the part under consideration, has an area of about 3,000,000 fedd.

† (*a*) 1 feddân = 1·038 acre.

(*b*) Here and throughout the Note, wherever an area of development is ment oned, it is understood that one-third of it is always lying fallow, one-third under cultivation by l guminous crops, and one-third under cotton, in contradistinction to Egypt, where, under the best conditions, the whole area is annually under crop.

thus obvious that large areas could be successfully guaranteed with the water available; 300,000 feddâns only, however, were estimated as being necessary to make the scheme financially sound, and further as this area seemed to be all that could be sufficiently populated in the immediate future, it was selected for development.

Present day information shows that, if a year like 1913–1914 should recur, 660,000 feddâns could be guaranteed water, and further, that the cultivation of well over 1,000,000 feddâns may be justified when the demand ultimately arises for such an area.

Natural Supply.

Discharges and gauges of the Blue Nile observed during ten years 1906-1915 have provided the necessary data for making a table, which is given as an appendix to this Note and shows the discharges passing Sennâr for given gauge readings.

The extent to which the Gezîra can be irrigated is affected by the nature of the crops to be grown at various seasons, the relation of their water requirements to the needs of Egypt, and the amount of storage water that can be provided. The best crop rotation and the supplies it requires have been determined by experiments at Tayîba since 1911 and Barakât since 1914. The Agricultural Department and the Plantation Syndicate are in agreement on the volumes actually required. These correspond well with the volumes said to have been pumped for the experimental stations. The supply required at headworks * is based on these figures, assumes that irrigation will begin

* Supply required at Headworks for 300,000 Feddâns Gross Area.

Period.	Cubic Metres per Feddân per Day.	Period.	Cubic Metres per Feddân per Day.
July 16 to 31	18 - 40	February	15
August	24	March	15
September	24	April 1 to 15	15
October	24	„ 16 „ 30	5 3
November	24	May	5 3
December	23	June	5 3
January 1 to 15	23	July 1 to 15	5 3
„ 16 „ 31	15		

If sown in time, cotton needs no waterings after March, nor leguminous crops after January. Allowance is, however, made up to April 15 for cotton. One-third of the area will be fallow.

These volumes assume that the gross area, including fallow, is 300,000 feddâns: less liberal allowances will be required as the gross area is increased and made more compact in shape; however, to be on the safe side, these allowances have been used throughout.

After April 15, five cubic metres per feddân per day at headworks is allowed for drinking, domestic requirements and gardens: as the area developed increases, this allowance, already a very liberal one, will become exceedingly so.

When comparing similar areas or supplies in Egypt and the Sudan, it must be remembered that the intensity of cultivation is much less in the latter, one-third of the land being always fallow or unirrigated.

The above figures allow 11,400 cubic metres per feddân of cotton and 5,500 cubic metres per feddân of leguminous crop at the canal head for the season.

fifty-seven kilometres from them and that losses in canals will be according to a liberal formula.*

From records available for eleven years—and they form part of a very low series for the Main Nile† — the average supply in the Blue Nile at the critical period during the low season is sufficient to guarantee the development of 800,000 feddâns.‡ The Nile flood of 1913 was in the main river the lowest recorded for 180 years.§ It was followed by a proportionately inadequate winter supply. It is the Blue Nile that makes the flood, and if in 1913 the flood in the Main Nile was lower than it had been for 180 years, it was no doubt the lowest for the same period in the Blue Nile; the winter supply in the Blue Nile most probably was also the lowest for the same period, for, while in the main river a very low flood might, owing to the intervention of the White Nile, be followed by a winter supply not low in the same proportion, no such assistance can augment the falling waters of the Blue Nile. The extremely low year 1913–1914 had in the critical period April 1 to 15 sufficient water adequately to supply 315,000 feddâns. In 1907–1908, the next lowest season of the eleven-year series on the Blue Nile¶ the total area cultivable would have been 530,000 feddâns.

Storage.

While the figures given above represent what the natural unaided river can do, it must be noted that to get the Blue Nile water on to the Gezîra plain entails the construction of a Dam on the river, with the consequent double advantage of making available, if it is required, all the water passing between January 1 and April 15, and providing additional storage when necessary. In Egypt to-day cultivation has outgrown storage, but has not been allowed to outgrow it by so much that a year of poor supply may not be tided over. The area under rice in such a year is usually reduced; in 1914 rice was practically prohibited, and the periods between waterings were lengthened for

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* Losses are assumed to correspond to those found in the most similar situation in Egypt. In practice they are expected to prove but a fraction of those adopted, owing to the nature of the Gezîra soils.

† These years form part of a series of seventeen years, throughout which the average of the yearly maximum flood levels at Rôda is lower than in any other series on record during the last 180 years.

‡ In preliminary calculations, when the area cultivable without storage was mentioned, it was assumed that regulation would enable full use to be made of the natural supply of the river in a particular period, *viz.* February 1 to April 15. In the present calculations, the same assumption is made, but for a much shorter period. The areas here given as cultivable without storage are those cultivable on the mean discharge of the lowest 15 days of the season. During the lowest period, April 1 to 15, the average supply for the eleven years was 140 cubic metres per second and the requirements of 800,000 feddâns at that period amount to 139 cubic metres per second.

§ There is a gap of twenty-five years in the records at the beginning of the last century.

¶ The recurrence of such years may be assumed as not taking place more frequently than once in ten years on the average.

other crops. In the Sudan, cultivation would not be allowed to extend so far that it would be impossible to tide over the lowest year by ceasing to water the leguminous crop earlier than usual, extending intervals between cotton waterings and even prohibiting them after a certain date. Where it is possible to obtain so much storage that it will balance the deficiency of the lowest year, even such measures become unnecessary. The Nile can be so controlled as to produce this complete independence of natural conditions both in Egypt and the Sudan for all areas of cultivation at present contemplated.

The contents of the reservoir * which will thus be formed in the valley of the Blue Nile by the Sennâr dam and used to supplement the river in its low stage amount to 467 millions of cubic metres, after deduction for loss by evaporation at the rate of one centimetre per day. This volume, combined with the natural volume of the river, would guarantee 660,000 feddâns on the 1913-1914 low-river basis.

On the 1907–1908 basis, the next lowest year in the recent series, the combined supply of river and reservoir would suffice for more than 1,000,000 feddâns.

Needless to say, development would not be confined to the area able to be guaranteed against low years alone, thus wasting large quantities of water in the majority of seasons, still less would it be limited to the area that can be guaranteed against a year like 1913–1914; a reasonable view of these facts would lead to the decision to cultivate well over 1,000,000 feddâns, were the other controlling factors, the requirements of Egypt, population and general development, in agreement with the engineering possibilities. When further areas are required storage can be found higher up in the Blue Nile Valley.

The present Gezîra scheme covers 300,000 feddâns, or about forty-five per cent of the area which it has been shown the river with the Sennâr storage would guarantee in the lowest year known to have occurred. These 300,000 feddâns form an area so comparatively small that not only could its full requirements be more than met at the lowest stage of the lowest year on record without the aid of any storage whatever, but also, should the Blue Nile go dry from February 1 till the rise of the flood—a hypothetical condition which for the sake of argument may be assumed as a contingency—it would still be possible, by means of the water which could be stored upstream of the Sennâr dam, to meet the failure and counteract its effect. Such failure of the Blue Nile is considered to be outside the range of possibility, but not even so extraordinary a phenomenon could affect the security of cultivation of 300,000 feddâns.

* The contents of the reservoir are based on the detailed contouring of the valley and are greater than former conservative estimates; further advantage has also been taken of the dam without increasing its height by arranging that the spill way culverts be closed to a greater height when storing water in extreme years.

It is estimated that the figures used in this Note are on the average not likely to be more than ten per cent from the truth either way. Against possible overestimate to this extent should be set the application of higher rates of seepage losses in the canals than are expected to occur. Obviously the margin of security is abnormally high, when, as calculation shows, 660,000 feddâns can be guaranteed from river and reservoir in the lowest known year, and it is only proposed at present to deal with 300,000 feddâns. During the years while the preliminary area is being put under cultivation information will accumulate, and when great extension is required it will be possible to estimate as closely as need be the capabilities of a supply which, it is sufficient at present to know, is very much more than ample.

Egypt and the Sudan.

As regards the relations between Egypt and the Sudan in respect of the Nile supply, the second six months of the year are the flood months, when water is abundant, and it has been proved that the crops to be grown on the Gezîra need be irrigated only during nine months, from July 15 to April 15. Thus the flood months largely bear the burden of their irrigation. During half-April, May, June and the first half of July, the Blue Nile can be left untouched except for domestic requirements (*see* page 2, footnote). As for January, February and March,* three post-flood months when irrigation of the Gezîra will be in progress, long before their requirements can reduce the Blue Nile's supply to Egypt, compensating storage will be available.

In average years, Egypt's supply at Aswân being below requirements from April 10 to July 15, or between March 10 and June 15 at Sennâr, no water should be taken from the Blue Nile throughout this period. The requirements of 300,000 feddâns in the Gezîra for the interval would be 255 million cubic metres.† This amount can be very amply covered by the Sennâr storage. In the

* The requirements of the 300,000 feddâns between January 19 and June 25 are about 500,000,000 cubic metres, *viz.* :—

	Cubic Metres.
January 19–31	59,000,000
February	127,000,000
March	140,000,000
April 1–15	68,000,000
„ 16-30	22,000,000
May	47,000,000
June 1–25	38,000,000
TOTAL	501,000,000

† 4½ million cubic metres daily in March for 21 days = 95 million cubic metres.
3 „ „ „ „ April „ 30 „ = 90 „ „ „
1½ „ „ „ „ May „ 31 „ = 47 „ „ „
1½ „ „ „ „ June „ 15 „ = 23 „ „ „
July 1–15 TOTAL ... ... 255 „ „ „

started on Feby 18th and been well over by August 1

lowest recorded year, Egypt's shortage would have lasted from February 18 to July 25, timed at Aswân, corresponding to January 18 and June 25 at Sennâr. The requirements of the 300,000 feddâns would have been 500 million cubic metres. To meet this there would have been an effective storage of 467 millions, a sufficient quantity for 280,000 feddâns. It is therefore obvious that with some restriction* of water supply 300,000 feddâns could be cultivated from the reservoir alone and Egypt suffer no diminution of the present Blue Nile supply even up to July 25. But long before 300,000 feddâns are cultivated, the White Nile dam will be finished and Egypt will possess at least 4,000 million cubic metres of new storage water.†

Of this quantity, far in excess of Egypt's requirements for many years to come, a portion might be reserved to make up for any gradually increased use of the Blue Nile by the Sudan. To develop 660,000 feddâns in the Gezîra, without at all reducing the natural supply in the Nile between January 18 and June 25, 1,100 millions of cubic metres must be found. About forty per cent could be provided independently at Sennâr; for the rest—630 millions—compensation can be made by reducing the available storage of the White Nile reservoir by under twenty per cent. Storage higher up the Blue Nile, ultimately necessary in any event for the full development of the Gezîra, may be obtained long before the Sennâr storage approaches exhaustion. As for Egypt, when the time has come that she has put into full use the balance of her new 4,000 million cubic metres of storage, she still need never regret the percentage of it earmarked as compensation for any reduction in the Blue Nile, because she can draw further upon the White Nile's wonderful resources. In the lowest years, 8,000 million cubic metres of water that pass Mongalla never reach the Main Nile, but are wasted in the marshes of the *sudd* region, and behind Mongalla are the great equatorial lakes with their possibilities of storage.

It is possible that the relations between the two countries might be defined by a series of definite declarations: the Sudan to undertake that until the White Nile dam is completed 300,000 feddâns shall be the maximum developed in the Gezîra; Egypt to agree that after the completion of the White Nile dam twenty per cent of its storage shall for, say, twenty years be earmarked as compensation water and thus allow the Blue Nile to be drawn on to an equivalent amount by the Gezîra. After the expiry of some such period, the compensation water should be released for Egypt by provision of other storage elsewhere in the Blue Nile than at Sennâr, or some arrangement should be made for further utilization of the White Nile.

* The cessation of waterings for cotton at the end of March, which in most cases would be the natural course of events, would be the only restriction required.

† Aswân reservoir contains normally about 2,400 million cubic metres. If a year with a flood as abnormally low as that of 1913 should occur as development proceeds it will not be possible to abstr from the river enough water to fill Gebel Aulia Reservoir up to 4,000 million cubic metres but the sequence of projects is s

Conclusions.

Summarized, the conclusions reached are these :—

The Blue Nile with its Sennâr dam can guarantee 660,000 feddâns of cultivation in the Sudan against the lowest recorded Nile ; similarly, in the next lowest year of the recent series it can guarantee more than 1,000,000 feddâns, and in years of average flow much more. Had not progress in the Sudan to wait upon population and general development, ordinary engineering practice would warrant the undertaking of more than 1,000,000 feddâns forthwith. In other words, the day the Sennâr dam is finished a new area of 1,000,000 feddâns lies open to cultivation, though it is not intended nor indeed is it possible for many years to cultivate such an area.

The only area to which cultivation will now be extended in the Sudan is 300,000 feddâns. This can be irrigated, with some small restrictions, from the Sennâr storage, and the Blue Nile continue to supply Egypt during its time of shortage as to-day. Before this area has all been put under crop Egypt will have built herself the White Nile dam. When, at some still distant date, it is thought expedient gradually to extend beyond 300,000 feddâns up to, say, 660,000 feddâns, the cultivation of such an area can still be carried out without detriment to Egypt, even should such a year as 1914 recur. All that will be necessary will be for a small proportion, not exceeding in any case twenty per cent., of the White Nile storage to be earmarked as compensation for abstraction made from the Blue Nile. In all other years of the recent low series over 1,000,000 feddâns could be cultivated without detriment to Egypt once the White Nile dam is constructed, and the small proportion of its contents, not exceeding 20 per cent., set aside as compensation water.

The stages of these developments will overlap, producing ample and continuous security of supply. Before the Sudan can deprive Egypt of any Blue Nile water, the White Nile storage will be ready with the bulk of its supply for Egypt and with a percentage in excess of Egypt's requirements for many years temporarily available as compensation for any abstraction made from the Blue Nile. So also, before Egypt is ready to use up such compensation water herself, either the Blue Nile will be further supplied from its own watershed or additional storage can be provided by controlling the great lakes or economizing the waste of water in the marshes of the sudd region, sources of supply inexhaustible by Egypt and which will leave her indifferent to even the most brilliant future of the Sudan Gezira.

M. MacDonald, *Adviser*,
Ministry of Public Works.

May 20, 1918.

APPENDIX A.

SENNAR DISCHARGE.

CUBIC METRES PER SECOND.

MONTH.	MEAN FOR ELEVEN YEARS 1906-1907 TO 1916-1917.	1907-1908.	1913-1914.
November	1,400	860	325
December	700	440	170
January	410	265	120
February	260	175	75
March	170	110	65
April	145	85	85
May	225	115	75
June	515	400	300
Mean	475	305	150

In preparing the discharge table on which the above is based, observations at Soba, Wad Medani, Wad Haddad, Sennâr, Makwar, and Hillet Hassan, just south of Sennâr, have been used. These observations extend over the years 1906-1915, and a mean curve has been drawn through them.

In applying this mean curve corrections have been used to make it more closely applicable to individual years.

The discharges are estimated to be on the average not more than 10 per cent. from the truth, and have been rounded off to the nearest 5 cubic metres.

APPENDIX B.

SENNAR DISCHARGE TABLE.

FALLING STAGE, IN CUBIC METRES PER SECOND.

Sennar Gauge Readings.	0	1	2	3	4	5	6	7	8	9
Metres.										
9·8	—	—	—	—	—	—	49	50	51	52
9·9	53	54	55	56	57	59	60	61	62	63
10·0	64	66	67	68	69	70	71	72	74	75
10·1	76	77	79	80	82	83	84	86	87	89
10·2	90	91	93	94	96	97	99	100	102	103
10·3	105	107	108	110	112	114	115	117	119	120
10·4	122	124	126	128	130	132	134	136	138	140
10·5	142	144	147	149	152	154	156	159	161	164
10·6	166	168	171	174	176	178	181	184	186	188
10·7	191	194	196	199	202	204	207	210	213	215
10·8	218	221	223	226	229	232	234	237	240	242
10·9	245	248	251	254	257	260	262	265	268	271
11·0	274	277	280	283	286	288	291	294	297	300
11·1	303	306	309	312	315	318	321	324	327	330
11·2	333	336	339	343	346	349	352	355	359	362
11·3	365	368	372	375	378	382	385	388	391	395
11·4	398	402	405	408	412	416	419	422	426	430
11·5	433	437	442	446	450	454	459	463	467	472
11·6	476	480	485	489	494	498	502	507	511	516
11·7	520	524	529	534	538	542	547	552	556	560
11·8	565	570	574	578	583	588	592	596	601	606
11·9	610	615	620	625	630	635	640	645	650	655
12·0	660	665	670	675	680	685	690	695	700	705
12·1	710	716	721	726	732	738	743	748	754	760
12·2	765	770	776	782	787	792	798	804	809	814
12·3	820	826	832	838	844	850	856	862	868	874
12·4	880	886	893	900	906	912	919	926	932	938
12·5	945	952	958	964	971	978	984	990	997	1,004
12·6	1,010	1,016	1,023	1,030	1,036	1,042	1,049	1,056	1,062	1,068
12·7	1,075	1,082	1,088	1,094	1,101	1,108	1,114	1,120	1,127	1,134
12·8	1,140	1,147	1,154	1,161	1,168	1,175	1,182	1,189	1,196	1,203
12·9	1,210	1,217	1,224	1,231	1,238	1,245	1,252	1,259	1,266	1,273
13·0	1,280	1,288	1,296	1,304	1,312	1,320	1,328	1,336	1,344	1,352
13·1	1,360	1,368	1,376	1,384	1,392	1,400	1,408	1,416	1,424	1,432
13·2	1,440	1,448	1,456	1,464	1,472	1,480	1,488	1,496	1,504	1,512
13·3	1,520	1,528	1,536	1,544	1,552	1,560	1,568	1,576	1,584	1,592
13·4	1,600	1,609	1,618	1,627	1,636	1,645	1,654	1,663	1,672	1,681
13·5	1,690	1,699	1,708	1,717	1,726	1,735	1,744	1,753	1,762	1,771
13·6	1,780	1,789	1,798	1,807	1,816	1,825	1,834	1,843	1,852	1,861
13·7	1,870	1,879	1,888	1,897	1,906	1,915	1,924	1,933	1,942	1,951
13·8	1,960	1,969	1,978	1,987	1,996	2,005	2,014	2,023	2,032	2,041
13·9	2,050	2,060	2,069	2,078	2,088	2,098	2,107	2,116	2,126	2,136

[NOTES—*See* next page]

In preparing the discharge table, observations at Soba, Wad Medâni, Wad Haddad, Sennâr, Makwar, and Hillet Hassan have been used after adjustment to correspond with Sennâr gauge.

The table is based on observations made during 1906–1915 while the river was falling. It applies approximately also to the lower portion of the rising stage.

As it is based on a large number of observations extending over a number of years, it does not apply equally well to all years. In some years there are not enough observations to establish definite corrections, but no considerable error will be made by using the table as it stands. The following notes may be made use of in applying the lower part of table :—

1906. Few observations available, but table approximately correct.
1907. Many observations ; discharges from table on the average about 10 per cent. low between 200 and 400 m^3 p.s.
1908. Few observations and not very consistent. Table probably about 5 per cent. high at lower levels.
1909. Few observations available. They indicate that discharges from the table may be on the average 30 per cent. high below 500 m^3 p.s.
1910. Few observations. They indicate that the discharges from the table may be about 20 per cent. high below 200 m^3 p.s.
1911. Few observations. Table about 20 per cent. high at low levels.
1912. (Table correct ; many observations available.)
1913. (Table about 5 per cent. high between 250 and 450 m^3 p.s. ; many observations available.)
1914. Table gives discharges on the average about 10 per cent. low between 70 and 180 m^3 p.s.
1915. A few observations all below 200 m^3 p.s. Table about 20 per cent. high.

These corrections are no doubt due, as has been proved to be the case at Aswân, to variations of river bed.

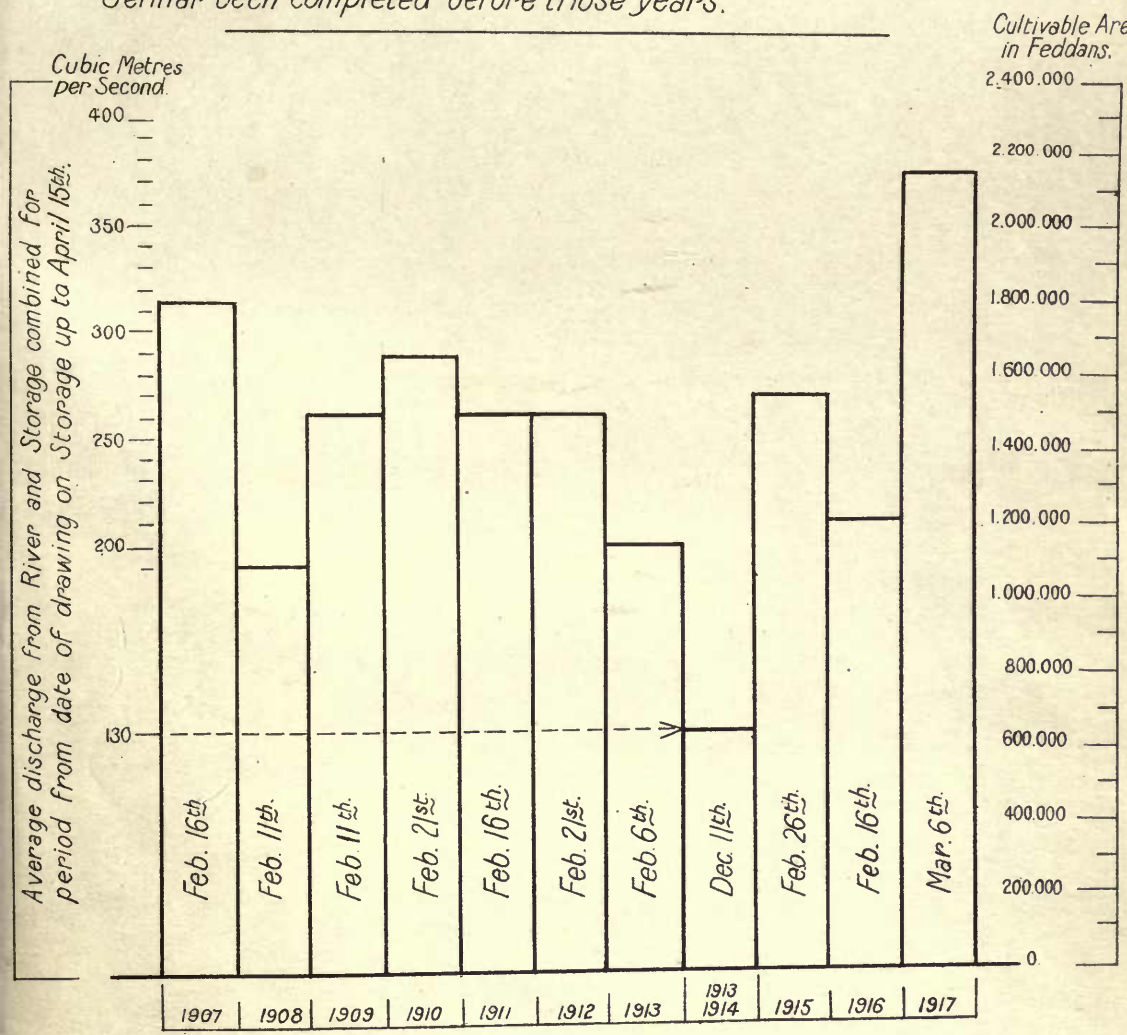
H. E. Hurst,

Acting-Director, Physical Department,
Ministry of Public Works.

May 14, 1918.

GEZIRA IRRIGATION SCHEME.

Areas cultivable with the discharge of the Blue Nile combined with effective storage of 400 millions M.³ showing dates on which storage would have been first used had the proposed works at Sennâr been completed before those years.



Note— Calculations have been made to the nearest 50.000 Feddans.

1913-14 being so low, water would have been drawn from the Reservoir in December, whereas in all other years this would not have occurred until February. It follows that, as the demand in December and January is greater than in the succeeding months, the average supply per day for 1913-14 is relatively greater than for other years.